Review of Saltwater Intrusion and Mitigation Studies and Models for Proposed Post Panamax Locks

Revisión de los Estudios y Modelos de Intromisión y Mitigación de Agua Salada para las Esclusas Pospanamax Propuestas

DHI Water & Environment

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Resumen Ejecutivo

Review of Saltwater Intrusion and Mitigation Studies and Models for Proposed Post-Panamax Locks

Executive Summary

November 2005

Review of Model Studies

Final Report
November 2005

1 EXECUTIVE SUMMARY AND CONCLUSIONS

In accordance with Work Order No. 18, Contract No. SAA – 151798, dated 13 April 2005 'Review of Possible Salt Water Intrusion and Mitigation Studies and Model for Proposed Post–Panamax Locks at the Pacific and Atlantic Sides of the Panama Canal' DHI Water & Environment has been commissioned by Autoridad del Canal de Panamá (ACP) to prepare a review of the studies undertaken to investigate salt intrusion.

The salt water intrusion studies are awarded to WL Delft Hydraulics and presented in Reports A, B, C, D and F, see the table below. This report describes the results of the review of these studies.

Study SAA-74337	
Report A	*Salt Water Intrusion Analysis Panama Canal Locks, Existing Situation, Report A June 2003, Delft Hydraulics*
Report B	*Salt Water Intrusion Analysis Panama Canal Locks, Future Situation: Post-Panamax Locks, Single Lift Locks, Report B September 2003, Delft Hydraulics*
Report C	*Salt Water Intrusion Analysis Panama Canal Locks, Future Situation: Post-Panamax Locks, Three Lift Locks, Report C September 2003, Delft Hydraulics*
Report D	*Salt Water Intrusion Analysis Panama Canal Locks, Future Situation: Post-Panamax Locks, Two Lift Locks, Report D September 2003, Delft Hydraulics*
Study SAA-135358	
Report F	*Salt Water Intrusion Analysis Panama Canal Locks, Future Situation: Post-Panamax Locks, Study, Modelling and Analysis of Salt water Intrusion Mitigation Systems for Revised 3-lift Lock Configurations, Report F April 2005, Delft Hydraulics*

The following observations have been made:

SWINLOCKS

The salt water intrusion into the Gatun and Miraflores lakes is simulated by the Salt Water Intrusion in Locks (SWINLOCKS) model. SWINLOCKS is a box model based on conservation of volume of water and salt. Measurements, theoretical analysis and numerical hydrodynamic (Delft3D) simulations empirically determine salt exchange coefficients. It integrates the different time scales into single events: equalising, density flows and ship movement. The model is used both for simulation of the salt exchange between locks as well for simulation of the salt exchange between the locks and sea and between the locks and the lakes. The model is designed for calculation of the salt water load on Miraflores and Gatun Lake.

Salt Exchange between locks

Based on independent salt intrusion computations it is confirmed that SWINLOCKS calculates correctly the salt exchange between the locks. The critical factor in SWINLOCKS is the exchange coefficients. Although the determination of the coefficients is associated with a large scatter it seems that the coefficients applied between the

locks are sound and robust. Field measurements and data collection within locks are adequate for the purpose although a large scatter was found. Only minor inconsistencies have been identified. It is concluded that the SWINLOCKS model describes the salt transport from lock to lock with sufficient accuracy.

Salt Exchange in Gaillard Cut

Very low salinity is observed near Pedro Miquel forebay (order of 0.1ppt). It is known that about 1% of the mechanical energy for ship movement is available for water column mixing. As the density difference (equivalent to 0.1ppt) is very low, an order of magnitude calculation gives that ship propulsion will mix the water column in Gaillard Cut over the vertical. As a result it must be expected that salinity will be transported back through Pedro Miquel Locks with the spillage water. Consequently, DHI expects that almost no salt will be transported from the Pedro Miquel Locks through the Gaillard Cut into the Gatun Lake. Whether this also can be expected to be the case for the new locks needs to be supported by numerical simulations.

Salt Exchange between Lock - Lakes

Salt intrusion into the lakes depends on the size of the ships, number of ship passages, lock operations, turn arounds and is a balance between salt inflow from the upper lock, salt density driven flow away from the lock and the salt outflow due to spillage. Salt concentrations decrease gradually away from the locks. It is the opinion of DHI that the variation in space and time of salt close to the lock is decisive for correct determinations of the salt outflow during spillage and thereby the net salt import/export.

A box model of the lakes with three compartments only can not describe the salt gradients near the locks. The SWINLOCKS model describes the salt exchange between locks and lake taking all the processes into account empirically. A box model approach alone to describe the salinity conditions in the lakes cannot be used to predict the present situation and the full consequences of the Post-Panamax locks. This has been demonstrated by a series of 3D hydrodynamic simulations of salt water intrusion.

Field Measurements in Lakes

Salinity levels in Gatun Lake and Gaillard are very low, less than 0.1ppt. The applied CTD instruments could not detect salinity below that level. The only conclusion drawn in Report A from the measurements was that salinity is less than 0.1ppt in Gatun Lake and Gaillard Cut. However, though salinity values are low, DHI expects the variation (ratio between salinity at forebay and central Gatun Lake) to be high. It is recommended that new measurements must be made in the vicinity of Gatun and Pedro Miquel Locks. In freshwater, ion concentration may equally consist of a number of salts other than Natrium Chloride. Conductivity is thus not equivalent to NaCl. It is recommended that the different salts that are present in the Lake water are measured in order to determine the origin of water. Conductivity must be measured with a high precision instrument designed for freshwater applications.

Water Saving Basins

In Report F Delft Hydraulics has calculated the effect of introducing water saving basins for the Post-Panamax Locks. In the SWINLOCKS model the water saving basins (WSB) are lumped together, described by the water volume and the average salt concentration in the basins. This approach can be confirmed by DHI.

Analysis of Mitigation Studies
A total of 10 mitigation schemes have been identified by Delft Hydraulics, Report F. This identification is considered complete. Concerning the determination of exchange coefficients for the salt pit mitigation scheme it is noted that it is based on 2DV Computational Fluid Dynamics simulations. However, the flow around the pit must be expected to be strongly 3-dimensional. The analysis must be complemented with 3D flow simulations.

Further Investigations
Based on the review summarised above, the following further investigations are proposed in order to complete the understanding of the salt water intrusion both in the present situation and after construction of the Post-Panamax Locks.

Improve the knowledge of the flow and salinity gradients in the lakes in the vicinity of the existing locks by a combination of measurements and 3D model simulations. Salinity measurements must be prepared for very low salinity values and supplemented with water sample analysis to define the chemical composition of the lake water as well as in the tributaries to establish the proper background salinity. Salinity measurements could be supplemented with tracer studies to provide an independent measure of the intrusion of seawater into Gatun Lake.

Determine by 3D modelling the flow and salinity gradients in the lakes in the vicinity of the Post-Panamax locks. Identify the salt exchange and possibilities for enhancement of mitigation schemes related to maximise return flow of salt water with spillage.

Determine the long-term salt concentration in the lakes (time scale years) after construction of Post-Panamax locks by a combination of 3D simulations and a lock model. A procedure for such a combination is not simple to establish, as the salinity close to the locks varies with each up- and downlocking, whereas far from the locks the variation is much slower with a time scale of month to years. To determine the long-term salt concentration it requires that both time scales are resolved in the model. An approach for simulating both time scales is described as part of the review.

Establish a long term monitoring programme of salinity and biology. This programme should be supported by a water quality (salinity model) of the canal system and an analysis of the biological sensitivity of the system with respect to salinity changes.